One of the most notable features of the computerized flight deck is its level of redundancy. For instance, not only is there one FMC for the pilot, but there is another for the co-pilot. The plane can fly with either FMC or manually.

If a major failure should occur, then backup liquid-crystal-display gauges and dials take over and provide critical readouts in place of the FMC.

Other subsystems

While the linchpin of the system is the FMC, there are other subsystems that are also important. Take the Flight Control Computer, for example. It receives inputs from the Inertial Reference System (IRU), the Flight Management Computer, the Thrust Management Computer, the Air Data Computer, the Radio Altimeter (RA), the Instrument Landing System (ILS), and the Control Wheel force transducers.

The Flight Control Computer commands the airliner's control surfaces (flaps, etc.) and engines, and responds to changing conditions by automatically altering their settings. Thus, if it appears that it would be more economical to fly over a storm than through it, the Flight Control Computer causes the plane to climb and bank in response to the new inputs.

While that is taking place, another segment of the system—the Thrust Management Computer—is computing and displaying autothrottle functions. It integrates signals from the engines, Air Data Computer, Thrust Mode Selector Panel, Flight Management Computer, and the throttle to provide autothrottle functions for all flight conditions.

For instance, with the throttles at full forward, the Thrust Management Computer provides maximum allowable engine power without exceeding operating limits. Further, performance management functions are performed in concert with the FMC, Autopilot Flight Director System, and other systems. Throttle changes during command operations, such as flight level changes, are performed automatically. And, in the event of a missed approach, the Thrust Management Computer provides the maximum allowable thrust when go-around is commanded by the flight crew.

Of even more interest from a technical standpoint is the new Inertial Reference Unit (IRU). While many people are somewhat familiar with the typical gyrocompass, the IRU uses a laser-controlled gyro for positioning. Unlike the traditional gimballed gyrocompass, there is only one moving part.

Called a Ring Laser Gyro, it uses a split laser-beam travelling in opposite directions around a closed triangular path. When angular motion is introduced, a frequency difference is detected and measured by photodiodes. That is converted to a digital output for use in the IRU computer. Three laser gyros are required for each IRU system, one for each axis.

In the align mode, the IRU is able to align itself to the local vertical, true north and an estimated latitude by gyrocompassing. No heading reference is required, because the IRU analyzes the spin vector generated by the earth's rotation to compute true north. Initial positioning must be entered through the Inertial Reference Mode Panel (IRMP). However, the last position of the previous flight can also be used to allow the IRU to compute a magnetic heading. The IRU also provides similar functions for navigation and attitude.

From all of that you can appreciate the level of sophistication needed not only in the hardware, but also the software. The programming for the Flight Management Computer alone took more than 100 man-years to create, test, and debug. It was then sent through exhaustive testing not only by the Boeing Co., but also by the Federal Aviation Administration.

It is a highly structured program, says Larry Bowe, head of engineering for Sperry Flight Systems, developer of the FMC. It's also a very capable one. It's possible for a pilot to program route and destination into the FMC and then let the computer fly the plane from takeoff to touchdown. Further, it will also alert the crew via the Engine Indication and Crew Alerting System that something is amiss in time for the pilot to take over.

The beauty of the total package is that it frees the pilot from many of the chores that he used to do manually. No longer does he have to compute the weight, temperature, weather, wind, and other parameters for a takeoff. With a few button pushes, the system does it for him. Long, in-flight computations are also eliminated. Thus, the pilot can now become a flight manager.

Pilot reaction

Pilots are ecstatic about the results. They like the displays and the possibility of using less fuel. They also like the Boeing "quiet, dark cockpit" concept, in which indications of system operations are reserved for conditions that require actions by the flight crew. There are very few distracting lights that signify normal operation on the flight deck.

In addition, the major functions of operation, status, and maintenance have been separated so they may be brought to the attention of the flight and ground crews selectively as they are needed.

So, what began as an attempt to save fuel by the airline industry has now turned into possibly the best aircraft in the air. In fact, if you fly on it, you'll never know whether the computer or the captain is doing the work.

Next month we'll present a detailed description of the displays and major subsystems of this system. **R-E**

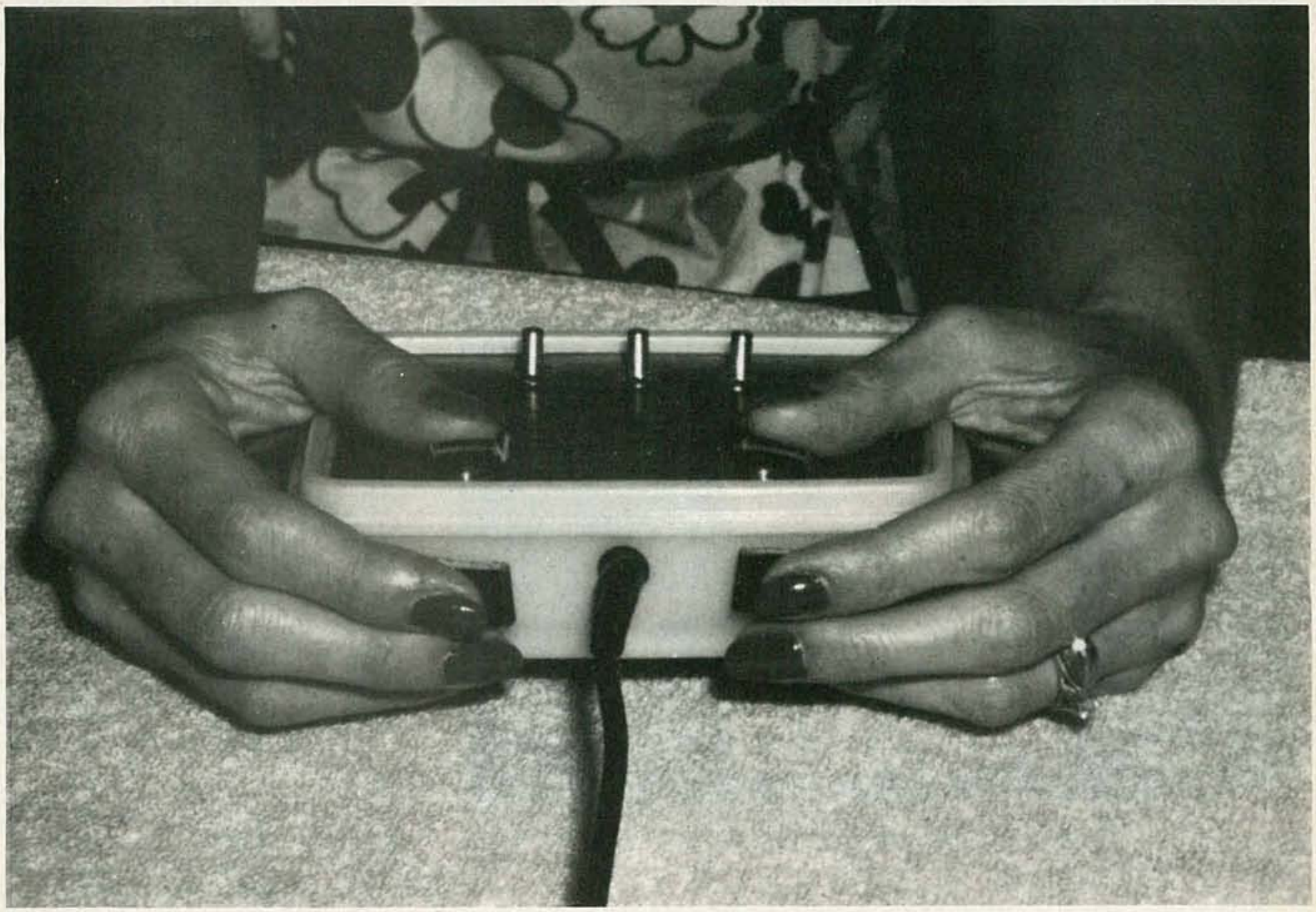
BUILD

Atari Videogame Controller

Add excitement and high scores to your home videogame. This easy-to-build joystick replacement for your Atari VCS gives you improved control plus a rapid-fire option and a tilt-activated fire switch.

DAVID J. SWEENEY

IF YOU ARE THE PROUD OWNER OF AN Atari *VCS* home videogame, you've probably spent more than a few evenings at home nursing a pair of rather sore hands. The reason why is that the Atari joysticks, which despite their shortcomings are still considered to be among the best available, are built to endure the excitement and pressure generated while shooting down those Space Invaders, or what have you, but your hands most certainly are not. Partially because of that, and partially because videogame players are always on the lookout for anything that might help improve their score, a whole industry (although, granted, a small one) devoted to supplying aftermarket game controllers has sprung up. Most of those, however, are simply better (we hope!) joysticks. What about a different approach? The joystick replacement described here, which, incidently, does not resemble a joystick in any way, will add a new dimension to your home videogame action. Among its advantages are that it is easily built, comfortable to use, and adds a couple of features not found in the standard Atari units—those are repeat-fire action and a tilt-controlled switch. What's more, the project is very economical to build and operate.



A SANDWICH BOX covered with wood-grained paper makes an inexpensive case.

Comparing the controllers.

The controller that is supplied with the Atari videogame system (see Fig. 1-a) uses five compression switches to control the game action. Four of those switches are operated by the joystick; the fifth is controlled by the red FIRE button; for simplicity's sake, we'll call those five switches UP, DOWN, LEFT, RIGHT, and FIRE (see Fig. 1-b). All of the switches are momentary, normally open, SPST types. Game software is designed so that the action on the screen is controlled by the opening and closing of those switches, which, in turn, is controlled by the movement of the joystick. In other words, if you move the joystick to the left, it will close the LEFT compression switch (more on that shortly), and the software will move the appropriate object (gun, ship, Pac-Man, etc.) to the left; moving the joystick up will move the object on the screen up, etc. Moving the joystick diagonally closes two switches at once, moving the object diagonally.

Any joystick substitute must also provide an arrangement of five switches. This device uses four pushbutton momentary SPST switches and one internal tilt-controlled mercury switch. Figure 1-c shows the location and function of those

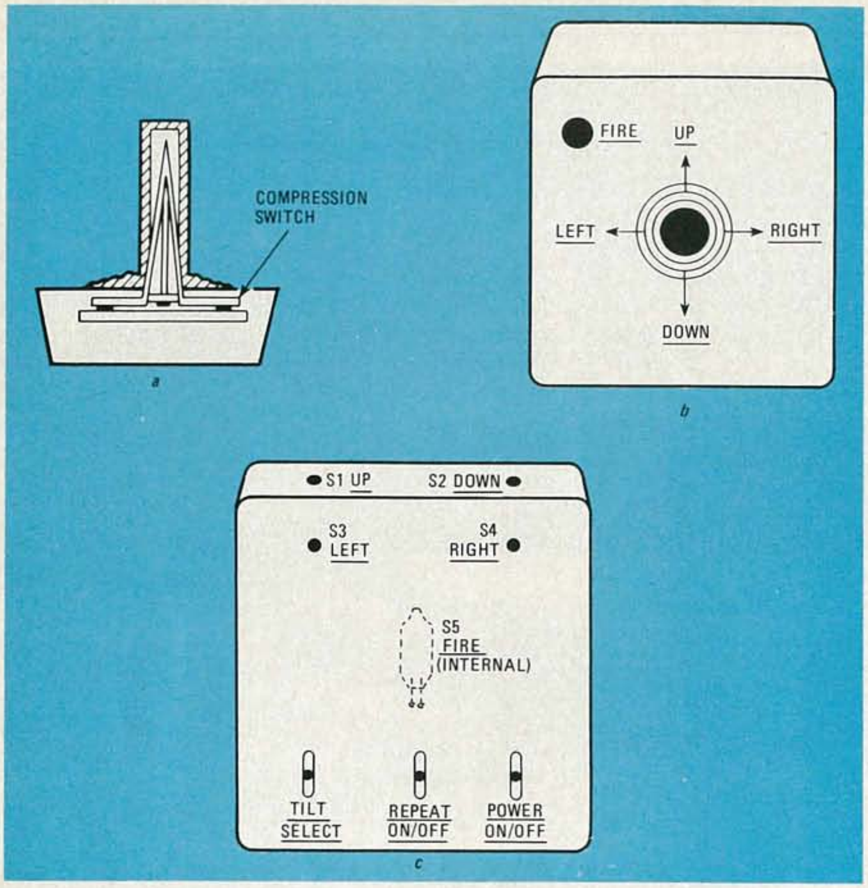


FIG. 1—ONCE YOU GET USED to the switch positions on the controller you're likely to throw your original joysticks away!

TABLE 1

	Switch	Location/Function	Joystick equivalent
Game switches	S1	Left forefinger	Up or Fire*
	S2	Right forefinger	Down
	S3	Right thumb	Left
	S4	Left thumb	Right
	S5	Internal	Up or Fire*
Setup switches	S6	Power on/off	—
	S7	Repeat on/off	—
	S8	Tilt select	—

*Selected by S8

switches, as well as the unit's three others—POWER ON/OFF, TILT SELECT, and REPEAT ON/OFF. Note that the Atari joystick's UP, DOWN, LEFT, RIGHT, and FIRE switches are replaced in our new controller by S1, S2, S3, S4, and S5 respectively. However, the function of two of those switches (S1 and S5) can be interchanged by using the TILT SELECT switch. That lets you choose whether you want to use the tilt switch (S5) to control firing or the upward movement of the object on the screen. Needless to say, whichever function is not controlled by the tilt switch will be controlled by S1. The switch functions/locations of our substitute controller, and their corresponding joystick functions, are summarized in Table 1.

As you can see in Fig. 1-c and the photos, S1-S4 are located so that they can be easily pushed by your forefingers and thumbs when the controller box is held. You're sure to find that this setup will make playing almost any game less tiring, and more enjoyable.

The circuit

The schematic diagram of the replacement controller is shown in Fig. 2. Aside from the switches we've already discussed, the bulk of the circuitry involves the repeat mode. Switch S7 is used to select either that or the single-shot mode.

In the repeat mode, you no longer need to push a button each time you want to fire a shot. Instead, each time you press the FIRE button or tilt the controller, depending on how the TILT SELECT switch is set, shots are fired at a rate of about 10-per-second for as long as the fire switch is pressed or the unit is tilted. The circuit used to do that is relatively simple, involving mainly a 555 IC oscillator and a reed relay. Basically, the oscillator is configured to open and close the relay at a rate of 10 Hz which, is about the fastest rate that you achieve manually. There is one other thing we should point out here: some games limit the number of shots you can take at a time—in Space Invaders, for instance, you can not take a second shot until the first has completely cleared the screen. Our controller can not override the software and change that.

Construction

Building our videogame controller is almost easier than describing it; it involves little more than installing the switches and repeat-mode circuitry into a suitable case. Let's turn our attention to that case for a moment. Considering the simplicity and low cost of our controller, it would seem a waste to house it in something that would cost more than the device itself. But, on the other hand, some sort of attractive case would be desirable. We decided upon a rather nice, if unlikely, compromise. The case you see in the photographs is nothing more than a refrigerator sandwich box, the kind that you can get in any discount store or supermarket; we dressed it up a little by putting some wood-grained self-adhesive paper on the lid. In use, we found that the case is easy on the hands and that it stands up well to the stress and perspiration sure to be generated when playing any videogame. In fact, the case has withstood eight months of hard use by a variety of players with no visible bad effects.

One problem did develop concerning the switches. First of all, they are rather small and easy to miss in the heat of "battle." Also, use over extended periods of time resulted in quite a bit of wear and tear on the fingers. The solution to both those problems was rather simple—an old belt was cut into strips that were used as switch covers. The strips (which measure 1 × ½ inch) are installed simply by punching a hole in one end and screwing them down next to the pushbuttons so that they lie over them.

The repeat-mode oscillator can be built using any construction technique and parts placement is not critical. The oscillator used in the prototype was built on perforated construction board and point-to-point wiring was used. The mercury TILT SELECT switch is mounted on the oscillator circuit board using a Velcro fastener as shown in Fig. 3. That mounting technique was used to allow for easy switch replacement in the event that it ever becomes necessary. The battery holder was made from a strip of aluminum that was shaped to fit the battery and secured as shown.

PARTS LIST

All resistors ¼-watt, 5%, unless otherwise specified
R1, R2—150 ohms
R3—47,000 ohms
R4—10,000 ohms
Capacitors
C1—2.2 μF, 50 volts, electrolytic
Semiconductors
IC1—555 timer
RY1—5-volts DC relay (Radio Shack 275-240 or similar)
S1-S4—SPST normally-open pushbutton
S5—mercury switch (Radio Shack 275-027 or similar)
S6—SPST toggle
S7—SPDT toggle
S8—DPDT toggle
B1—9-volt battery
Miscellaneous: cord from Atari joystick, case, perforated construction board, hardware, strain relief, battery clip and holder, etc.

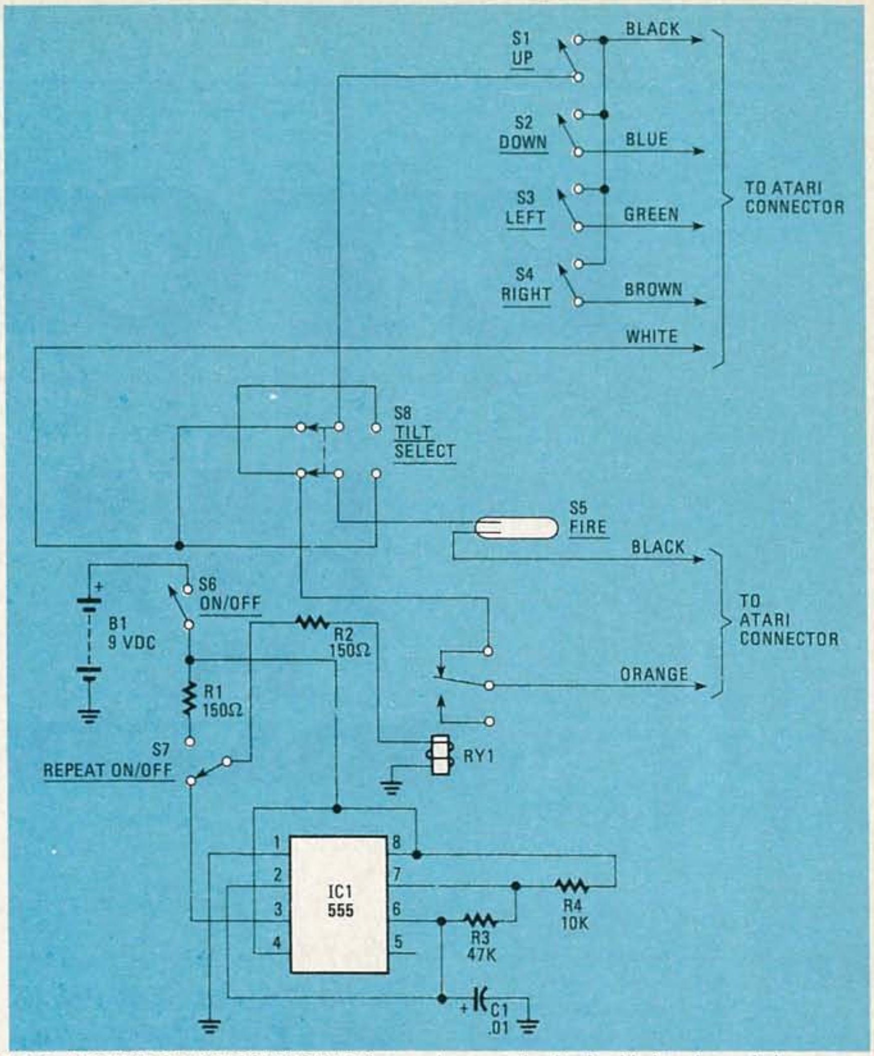


FIG. 2—HOOKUP OF THE CONTROLLER is easy because the Atari cable is color coded.

Before installing the oscillator in the case, check it for proper operation. The easiest way to do that is to apply power and check to see if the relay opens and closes at a rate of between 8 and 10 times-per-second. Also, it is very important to make sure that there are no shorts in the circuit. Keep things as neat as possible—if the nine-volts from the battery were somehow applied to the controller's outputs, costly damage to the Atari console might result.

Hooking it up

To attach the controller to the console, you can use the cable and plug from an old controller, or you can make up your own 6-conductor cable. If you would rather not cannibalize a controller and wish to make your own connector, the pinout diagram shown in Fig. 4 can be used to help you wire a standard DB-9S socket for direct connection to your Atari console. (Note that both black wires in Fig. 2 are connected to the same terminal on the DB-9S.) In either event, the multiconductor cable should be connected to a terminal strip as shown in Fig. 3, and all subsequent connections should be made from that strip. As always, be sure to provide some type of strain relief for the cable where it enters the case.

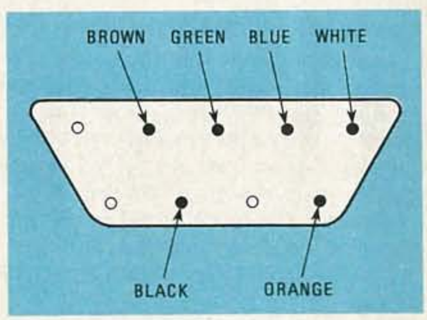


FIG. 4—THIS PINOUT of the socket on the Atari joystick cable can help you to wire your own DB-9S socket.

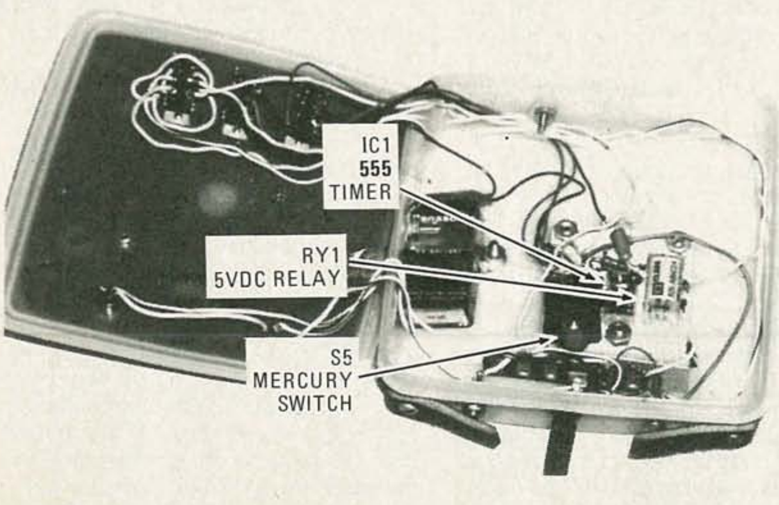


FIG. 3—TILT-SWITCH SENSITIVITY can be made adjustable by mounting the Velcro fastener on the wall of the case instead of on the circuit board.

Aside from the relief the controller provides for your hands, the tilt switch and the repeat function allow you to play almost any game more aggressively. The sensitivity of the controller could pose a problem in games that require a light touch, such as Activision's *Skiing*, but should help you get higher scores when you play most other Atari-compatable games. You'll need a bit of practice to master the different motions required by the controller, but once you do, and once you see the kind of scores you'll be running up, you'll probably never go back to the standard Atari joysticks. **R-E**